XXIV. COGNITIVE INFORMATION PROCESSING*

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RESEARCH OBJECTIVES

This group consists of three closely related subgroups working on Cognitive Processes and Pattern Recognition, Picture Processing and Image Transmission, and Sensory Aids for the Blind and the Deaf-blind. The general research interests of the three subgroups are: (1) definition and evaluation of the operating characteristics of a human being, especially with respect to the higher mental functions, (2) efficient transmission of pictures and the related problem of defining objective measures of subjective picture quality, and (3) the communication theory and technology relevant to acquisition and processing of visual information for display to the nonvisual senses, and the psychology of human utilization of such information.

1. Cognitive Processes and Pattern Recognition

(a) Interaction of Visual, Linguistic, and Motor Systems

This research is concerned with the uptake of cognitive information from environment, the form of its storage and its availability, and the control of action upon environment.[1,2] The experiments for this work are directed at two phenomena. Studies of information comprehension and availability involve bilingual adults who are given some information in one language that they know and are tested for it in the other. Research on control of action is implemented by textual material presented in some geometrically distorted form which the adult learns how to read or write.

We shall explore some of the temporal properties of the interlingual facilitation, and study the limits of the phenomenon by presenting bilingual subjects with material in various combinations of the two languages which they are capable of reading, and in various auditory combinations.[3-6]

(b) Handwriting Analysis and Synthesis

The production and reading of cursive writing represents a complex human cognitive process and a behavioral skill that is learned by almost all literate people. A detailed description of the structure of these processes appears to be feasible, and may shed light on the general organizational principles governing the acquisition of cognitive skills.[7-13]

Reading and writing are very complex skills. We have used them as paradigmatic cases in the problems of pattern perception and pattern production, and as techniques

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for getting at the voluntary control of the complex motor skills that humans exhibit.

(c) Invariants of Visual Information Related to the Perception of Motion and Depth

This project is addressed to the task of describing the organization of the visual environment in terms of certain physical, physiological, and geometric relations that are preserved when the nature of the perception in nonveridical, as in perceptions of apparent motion or depth illusions. It would appear that the postulates employed implicitly or explicitly by the observer in synthesizing his perception can be altered by context, or by linguistic instructions which in turn provide a systematic restructuring of the visual environment.

2. Picture-Processing and Image Transmission

(a) Bandwidth Compression

The purpose of this research is to devise and investigate ways of reducing bandwidth requirement in picture transmission, by utilizing the inherent statistical constraints in pictures and the properties of human vision. We are interested in two problems: (i) How much bandwidth reduction can one achieve, if no restriction is put on the complexity of the scheme? (ii) What is the performance of relatively simple bandwidth compression schemes? Whenever possible, the various schemes are simulated on digital computers. Special input-output equipment has been constructed to facilitate communication with the computers.[14-19]

(b) Picture Quality Evaluation

The objective of this research is to develop and evaluate procedures for testing the subjective quality of pictures, to develop standards for rating picture-transmitting systems, and to develop analytical criteria for mathematical optimization of such systems.[20-22]

3. Sensory Aids for the Blind and Deaf-Blind

(a) Mobility-Aids Simulation

We propose to develop a Simulator Facility for investigation of the basic requirements for sensory-aid systems for the blind and deaf-blind. A principal use of the facility would be the simulation of mobility-aid systems, enabling a sightless subject to experience, in real time and real space, the operation of hypothetical mobility aids. The monitoring and data-processing capabilities of such a facility would provide flexibility and control in basic experimentation on human information requirements, and would enable us to optimize the performance of specific systems before major investment of effort in realization of the complete system.

(b) Tactile Communication

For some time, we have been engaged in studies of tactile communication. Experimental evidence obtained here and elsewhere[23-25] indicates that higher information transmission rates should be obtainable through more sophisticated coding and higher dimensionality of the display. We propose to continue with the communication experiments now in progress on multidimensional, multimodality display, and with the development of computer-controlled and optical-scanner-controlled tactile matrix displays that are suitable for the presentation of Braille-like patterns, letter shapes, and outline pictures, for research in tactile perception.[26-28]

(c) Special Data-Processing Problems: Grapheme-to-Phoneme Translation of English Words

To generate synthetic speech from printed English words (or their symbolic equivalents) either as a reading-aid for the blind or for the purpose of machine-to-man communication, a process of grapheme-(alphabets, punctuation marks, etc.) to-speech-sound-elements conversion is needed. Phonemes are convenient discrete symbols of speech sounds. Recent research activities[29,30] on phoneme-driven speech synthesizers are beginning to show some results; however, the problem of grapheme-to-phoneme translation remains to be solved.

This research is a systematic study of English words and their pronunciation. Our objective is the derivation of the translating algorithms that can be implemented reasonably on logical machines.

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A. COGNITIVE PROCESSES

1. DYSLEXIC PERFORMANCE ON TRANSFORMED TEXT

College students who learn to read English text that has been subjected to a geometric transformation[1] exhibit a characteristic order of difficulty in their performance.

Text in mirror image is the most difficult to read, text rotated in the plane of the paper is "easy," and text inverted top to bottom falls in between. It takes a subject approximately 1.3 minutes to read a page of normal text aloud, approximately 3.3 minutes to read text rotated in the plane of the paper, and 5.3 and 5.6 minutes to read inverted text and mirror-image text, respectively.

These results are difficult to interpret. Does the task of decoding geometrically transformed text require the participation of "spatial operators" – unique algorithms appropriate for each function – or are all of the transformations decoded in the same way, by means of some slow quasi-problem-solving strategy? One way of testing the question is to learn whether the order of difficulty that we observe among the transformations is preserved when transformations are summed, e.g., when rotation and letter reversal or reflection and letter reversal are present. Results from tests of this kind have been previously described. A second way is to find the order of difficulty that perceptually handicapped individuals reveal.

One form of perceptual handicap is called dyslexia. This disturbance is characterized by poor performance on reading tests and other language-based materials by children and youths whose intelligence is normal to superior. Letter reversal, inversion, rotation, and many other distortions characterize their reading. One might infer that these distortions represent a malfunction of the "operators" of greater or less severity. That is, if the letter reversals and word inversions that characterize dyslexia[2] are due to the hyperactivation of an operator, or represent the failure of other mechanisms to preserve the physical order of objects in their psychological representations, one might find that the order of difficulty of geometrically transformed text revealed by normal readers would not be preserved by dyslexics. Consequently, we tested eight youths diagnosed as "dyslexic" by requiring them to read textual material that had been transformed.

The eight youths, all males, were between 16 and 20 years of age, and were selected randomly from a larger population, all of whom had experienced reading difficulties and were receiving special tutoring in reading. Their reading achievement levels, measured by standard tests, were between grades 3 and 10. Reading aloud proved to be a formidable task for them, and so the quantity of material that they were required to read in their tests was much less than would be given to normal subjects. The table below gives the time in minutes which these subjects took to read aloud 10 lines of text. For the purpose of comparison, the time needed by college freshmen to read the same amount of material is also shown.

	Normal	Rotated	Inverted	Reflected
Dyslexic	1.5	6.5	8.9	9.2
Normal	0.6	1.5	2.3	2.6

The principal facts are that dyslexics take much longer to read material aloud than normals do, as expected from their diagnosis; any transformation creates a far greater percentage impairment for dyslexics than for normals; and, on the average, the order of difficulty of the transformations found characteristically among normals also holds for the dyslexics. With respect to the latter, however, when the data are examined individually we find that exactly half of the dyslexics find reflection more difficult than inversion, while inversion is more difficult than reflection for the other half.

Anecdotal evidence may be more informative here than the numbers. Normal subjects faced with these transformations work out their difficulties by analogizing the transformation of one letter to a letter or letter sequence that puzzles them. They take a standard, say, and decode it. Letters such as r or R, k, g, and the like, are relatively unambiguous under transformation, and can be used as examples to aid in decoding ambiguous letters such as d, s, m, q, and the like. The dyslexics, on the other hand, are often unable to follow this strategy; the information available from a successful decoding of one letter is not very helpful for the decoding of another. The simplest hypothesis to account for this is that the difficulty lies in their generally poor achievement in dealing with spatially transformed material, but, of course, this is not the only available hypothesis. The results, in any case, demonstrate that whatever the difficulty is that produces dyslexia, it is not one that makes it easier for a dyslexic to recognize transformed material than it is for a normal. The disturbance does not facilitate rectification of a distortion; but it does distort normal material. This lack of symmetry raises further questions about this disturbance.

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